2017 Design Training Expo

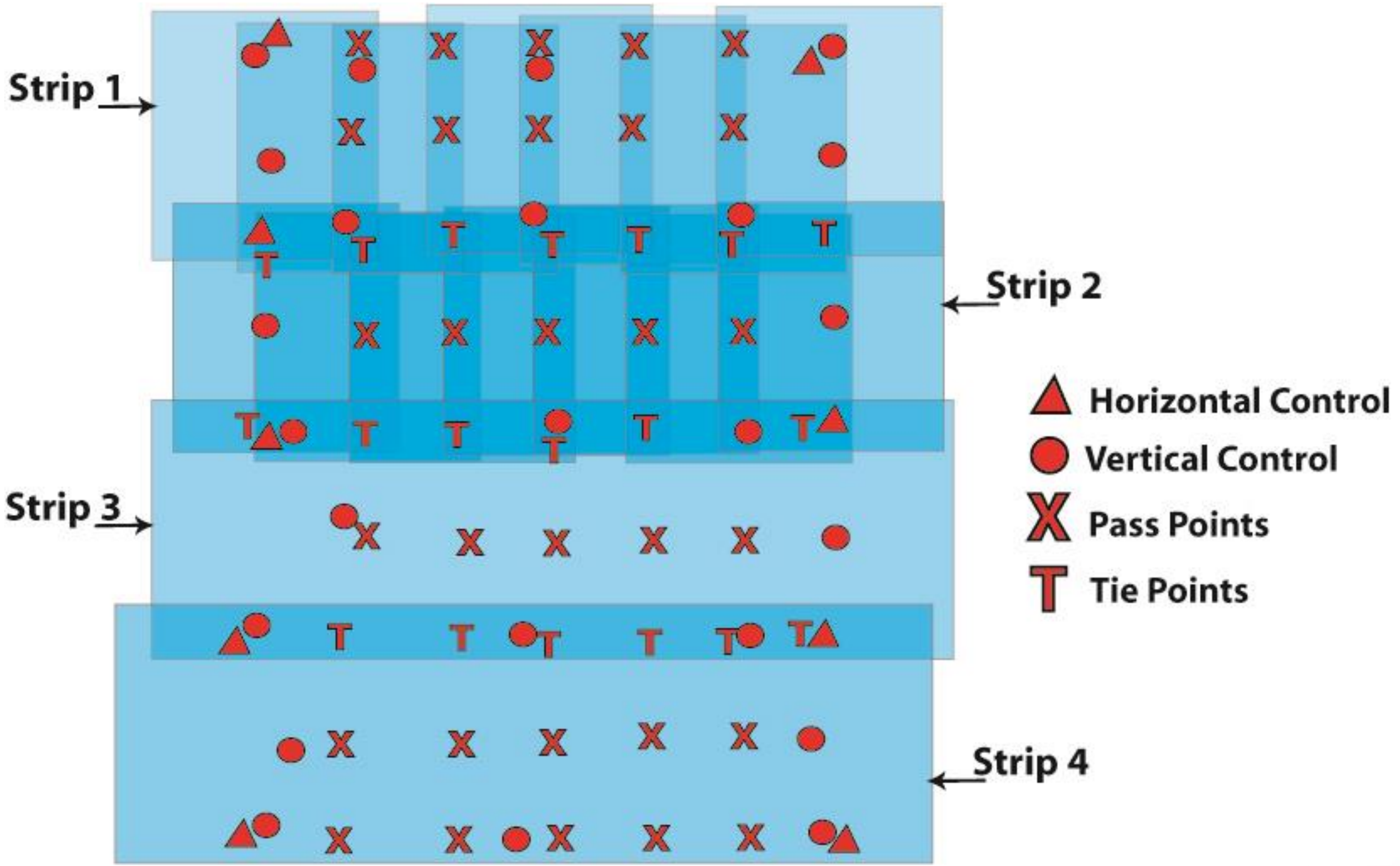
3D Surface Modeling Using Bentley Context Capture

Agenda

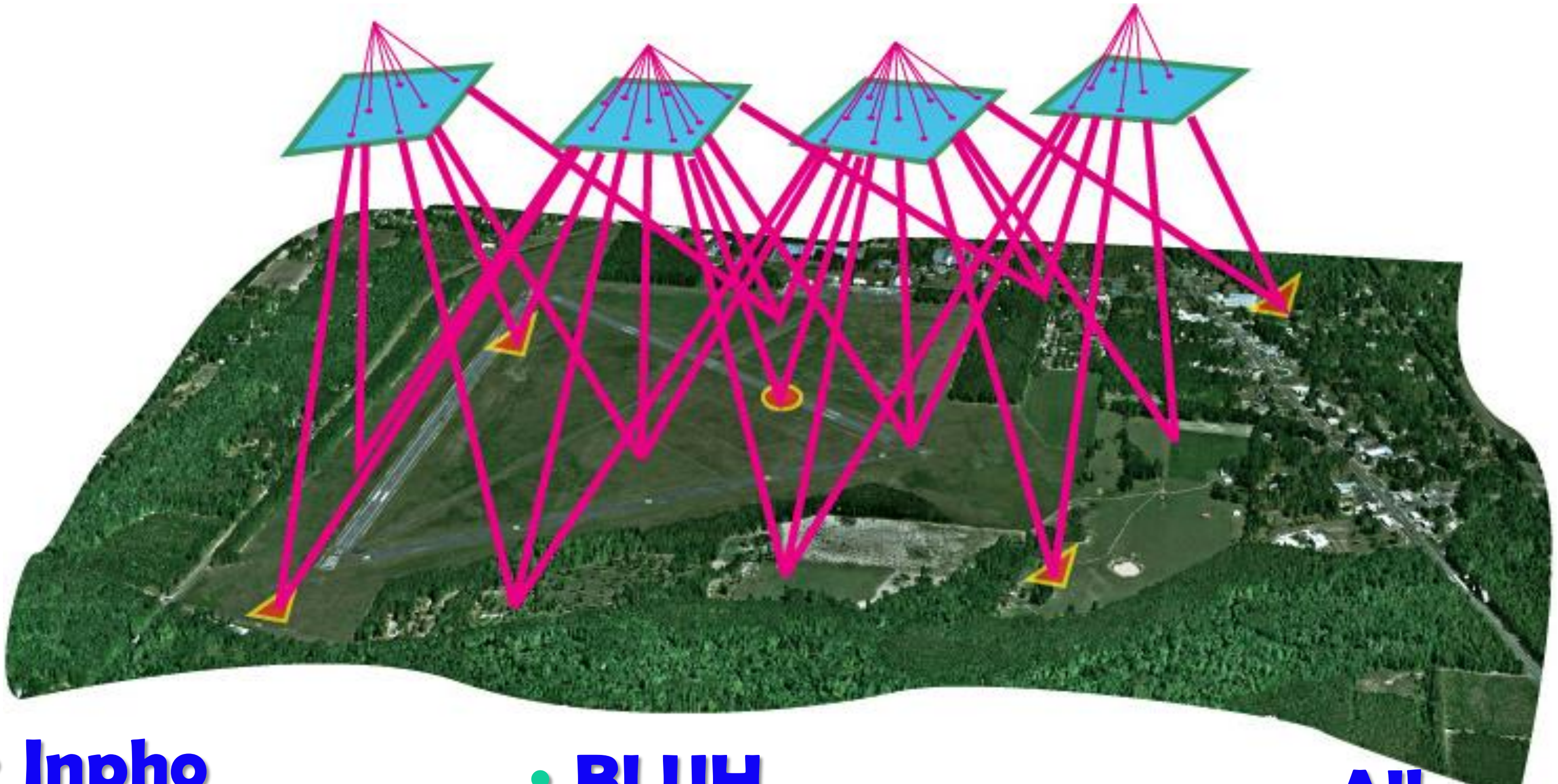
1. Multi-Ray Photogrammetry
    - Brief Overview of Photogrammetry
        - Aero-triangulation
        - Self-Calibration
        - Advent of Multi-ray and Computer Vision

    (Microsoft Research and University of Washington)
    - Sensors (Camera Systems)
        - Camera Features Needed
        - Sensors (Camera Systems)
        - Sample Demo with Bentley Context Capture

A typical Aerial-Triangulation Layout



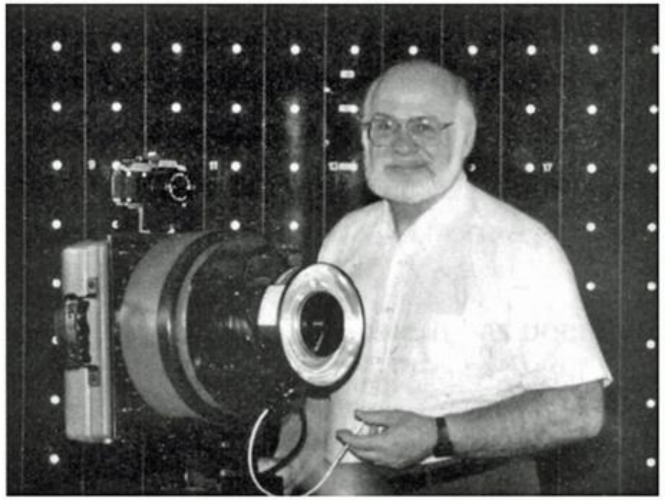
Aerial Triangulation - Bundle Adjustment



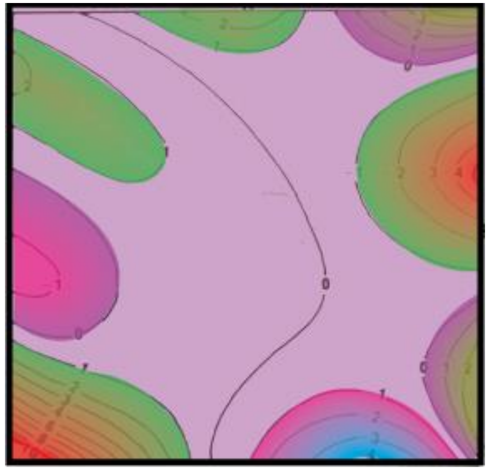
- Inpho
- Aerosys
- Leica LPS
- Socet GXP
- BLUH
- BINGO
- Intergraph
- Photomod
- Albany
- JFK
- PC Giant

Self-Calibration

Dr. Brown introduced Self- Calibration in the bundle adjustment.



Dr. Duane Brown
History of Photogrammetry
Center for Photogrammetric Training



Anomalous Distortion

ASPRS

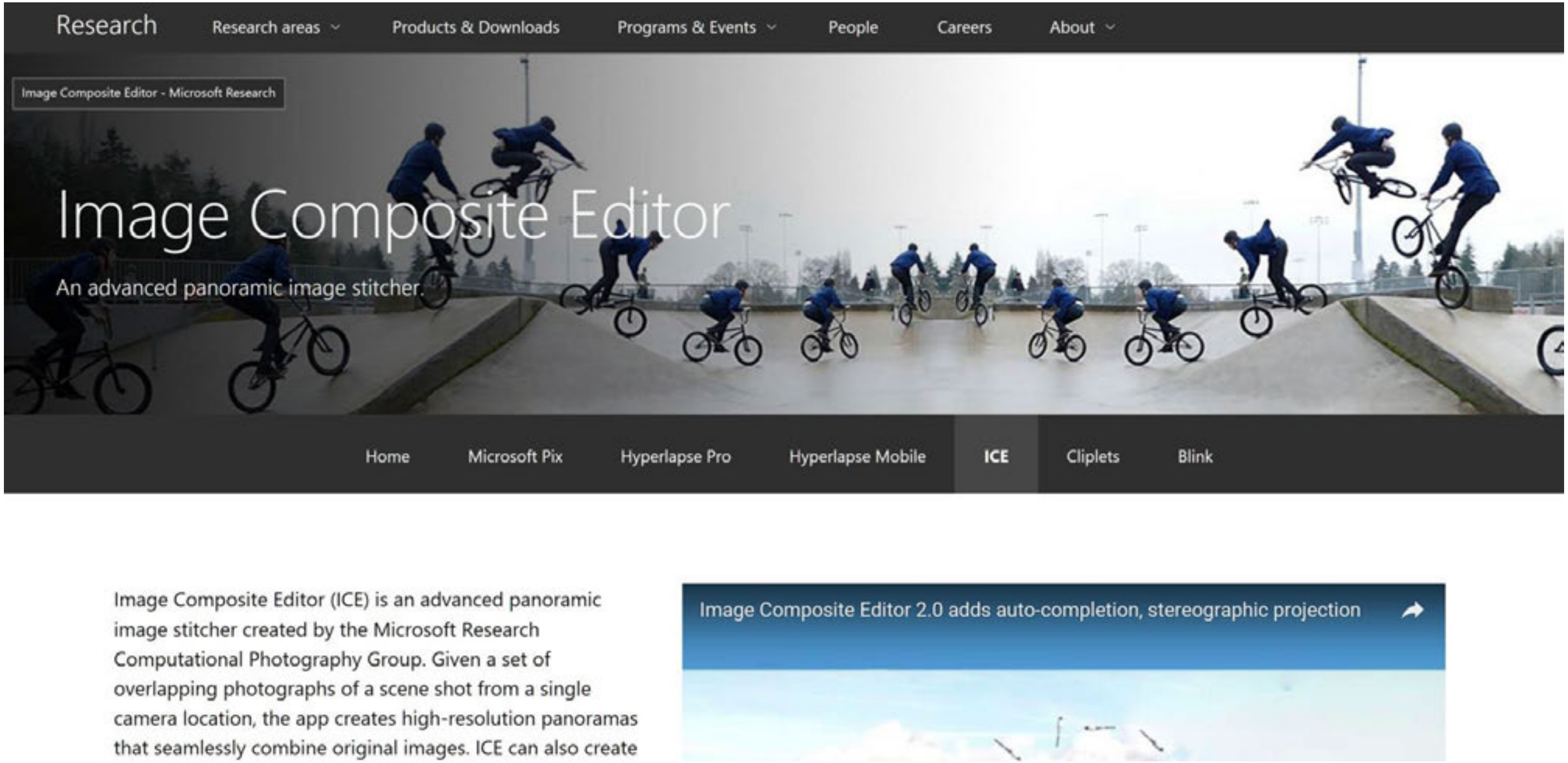
Self calibration Improves:

- the accuracy
- the reliability of the photogrammetric adjustment

http://www.geodetic.com/v-stars/what-is-photogrammetry.aspx

Microsoft (ICE Project)

https://www.microsoft.com/en-us/research/product/computational-photography-applications/image-composite-editor/



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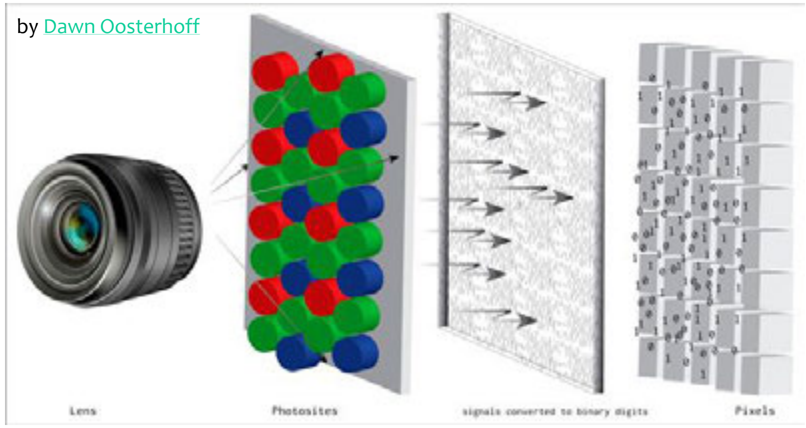
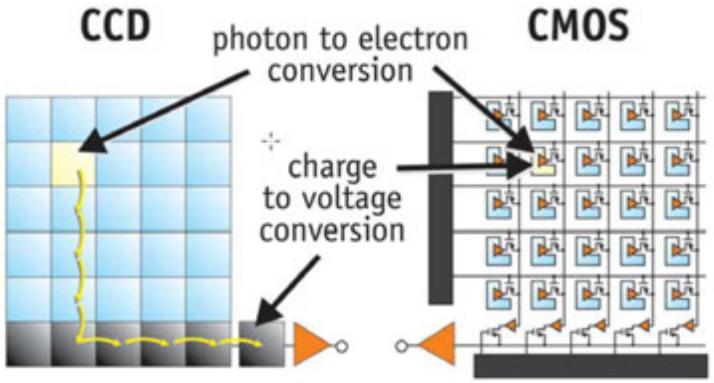
State of the Art Sensors



DR - brightest area and the darkest area an image sensor can process without saturation.



CCDs move photogenerated charge from pixel to pixel and convert it to voltage at an output node. CMOS imagers convert charge to voltage inside each pixel.

Dynamic Range (DR)

- Human eye - 90 dB
- Camera film - 80 dB
- CCD or CIS - 65 to 75 dB
- State of the art CIS - 150 dB

CCD – Couple Charged Device

CIS – CMOS Image Sensors

CMOS – Complimentary Metal Oxide Semiconductor

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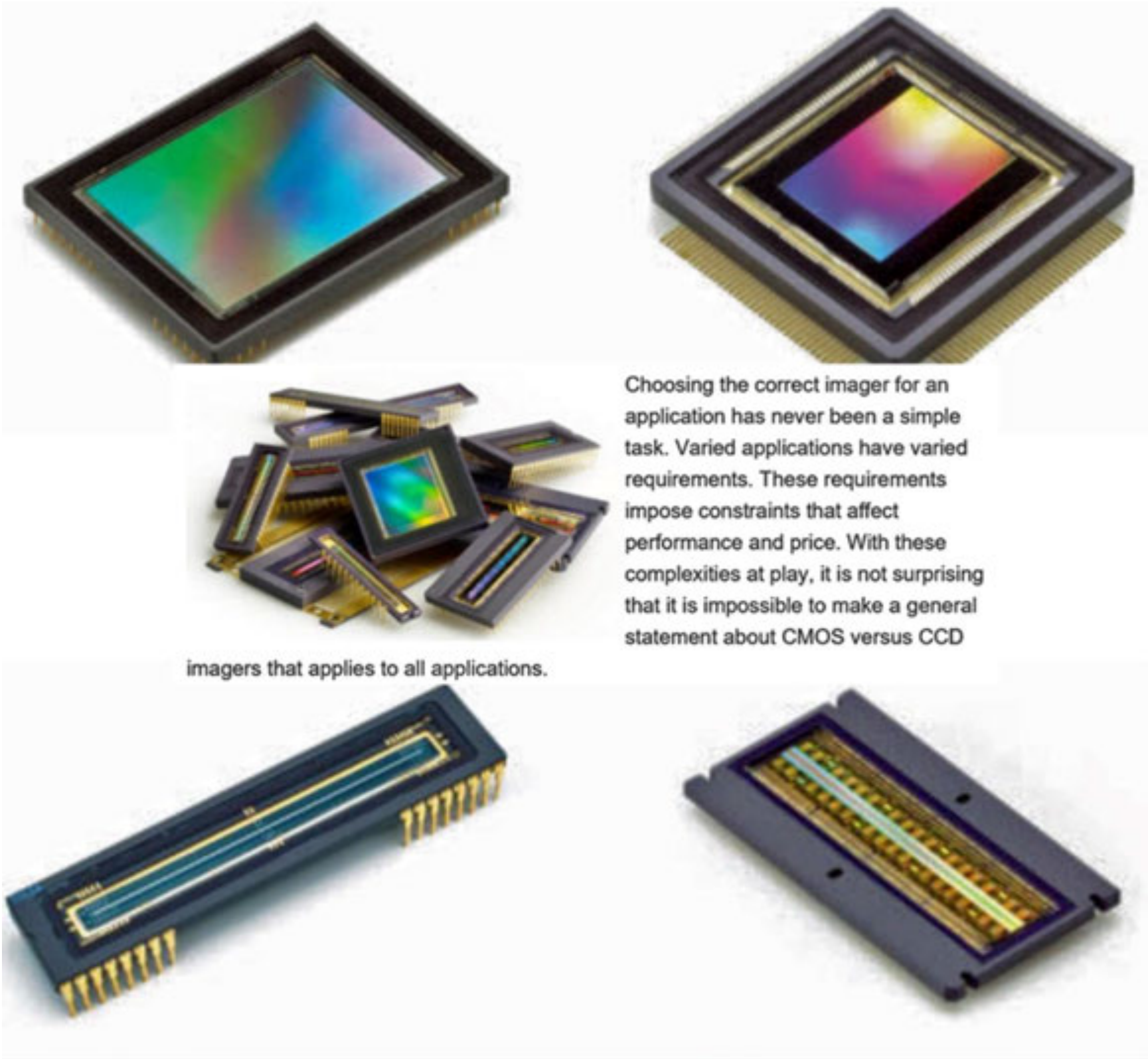
CCD & CMOS Varied applications have varied requirements



Teledyne DALSA CCD (left) and CMOS (right) image sensors

- UAS
- Close Range
- Metrology
- Forensic
- Archeology
- Environmental
- Volumetric Surveys
- Autonomous Vehicles
- Microscopy
- Photogrammetry

Is Higher Megapixel better ?

by Romanas Naryškin
Photography Life

Nikon Df VS Nikon D610

First, let's go over the key specifications:

	36mm x 23.9mm	35.9mm x 24.0mm
Sensor Size		
Sensor Pixel Size	7.3 microns	5.6 microns
Sensor Resolution	16.2 Mp	24.3 Mp
Image Size	4928 x 3280	6015 x 4015

Nikon Df vs D610 Specification Comparison

Camera Feature	Nikon Df	Nikon D610
Sensor Resolution	16.2 Million	24.3 Million
Sensor Type	CMOS	CMOS
Sensor Size	36×23.9mm	35.9×24.0mm
Sensor Pixel Size	7.30µ	5.96µ
Low Pass Filter	Yes	Yes
Sensor Dust Reduction	Yes	Yes
Image Size	4,928 × 3,280	6,016 x 4,016
Native ISO Sensitivity	ISO 100-12,800	ISO 100-6,400
Boosted ISO Sensitivity	ISO 50, 25,600-204,800	ISO 50, 12,800-25,600
HDR Support	Yes	Yes
Exposure Bracketing	2 to 5 frames	2 to 3 frames
Built-in GPS	No	No
Wi-Fi Functionality	Eye-Fi Compatible, WU-1b	Eye-Fi Compatible, WU-1b
Battery	EN-EL14a Lithium-ion Battery	EN-EL15 Lithium-ion Battery
Battery Life	1400 shots (CIPA)	900 shots (CIPA)
Battery Charger	MH-24 Quick Charger	MH-25 Quick Charger
Weather Sealed Body	Yes	Yes
Build	Top and Rear Magnesium Alloy	Top and Rear Magnesium Alloy
USB Version	2.0	2.0
Weight (Body Only)	710g	760g
Dimensions	143.5 × 110 × 66.5mm	141 × 113 × 82mm
MSRP Price	$2,749 (as introduced)	$1,999 (as introduced)

The benchmark is a ***full-framed sensor***—a sensor with the same dimensions as a frame of 35mm film; that is, 36 × 24 mm

Does Size Matter? New Image Sensors Bring More Pixels, More Problems by Dawn Oosterhoff

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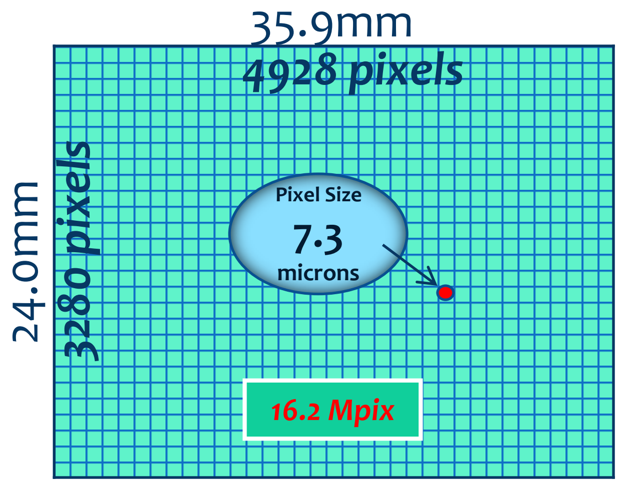
Values to know !

Nikon D

Image Size 4928 x 3280
Sensor Pixel Size 7.3 microns
Sensor Resolution 16.2 Mp
Sensor Size 35.9mm x 24.0mm

Image Resolution = 4928 x 3280 = 16.164 Mpix



Compute:
Sensor Resolution
Given Sensor Size &
Pixel Size =

35.9mm x 1000 = 35900 microns 35900/7.3 = 4917.80
24.0mm x 1000 = 24000 microns 24000/7.3 = 3287.67

4917.8 x 3287.67
= 16.168 M pix

Compute:
Sensor Size
Given Image Size &
Pixel Size =

4928 x 7.3 = 35974.4 microns = 35974.4/1000 = 35.9 mm
3280 x 7.3 = 23944 microns = 23944/1000 = 23.9 mm

Compute:
Sensor Pixel Size
Given Image Size &
Sensor Size =

35.9 x 1000 = 35900 microns = 35900/4928 = 7.285 microns
24.0 x 1000 = 24000 microns = 24000/3280 = 7.317 microns

Avg. Sensor Pixel Size = 7.3 microns

Multi-ray Photogrammetry

Multi-ray Photogrammetry

- Multi-ray photogrammetry is not exactly a new technology, rather a specific flight pattern with a very high forward overlap (80 percent, even 90 percent) and an increased sidelap (up to 60 percent). The result is considerable redundancy, critical for robust automated matching. One pixel on the ground is visible in up to 15 images
- Multi-ray photogrammetry has created a significant change in photogrammetry with the advent of the digital camera and a fully digital work flow.

"Photogrammetry versus Lidar: Clearing the Air"

Alexander Wiechert *is general manager at Vexcel Imaging GmbH, a Microsoft company in Austria. He holds degrees in Aerospace and Aeronautics and in Business Administration.*

Dr. Michael Gruber *is chief scientist at Vexcel Imaging GmbH.*

Professional Surveyor Magazine

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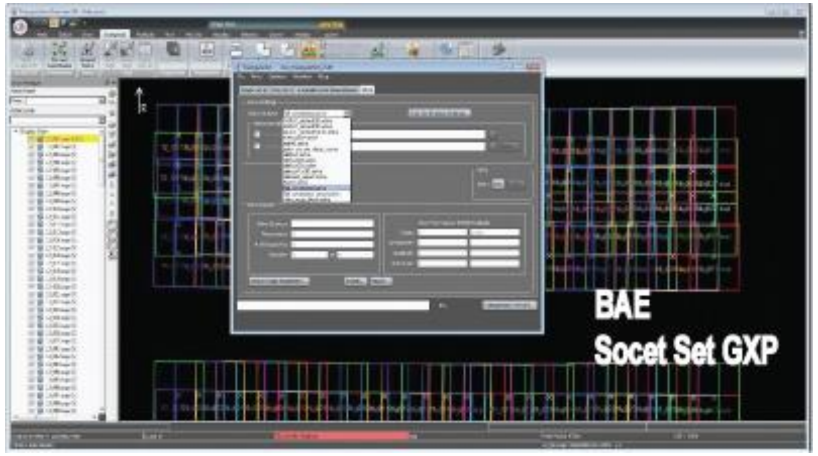
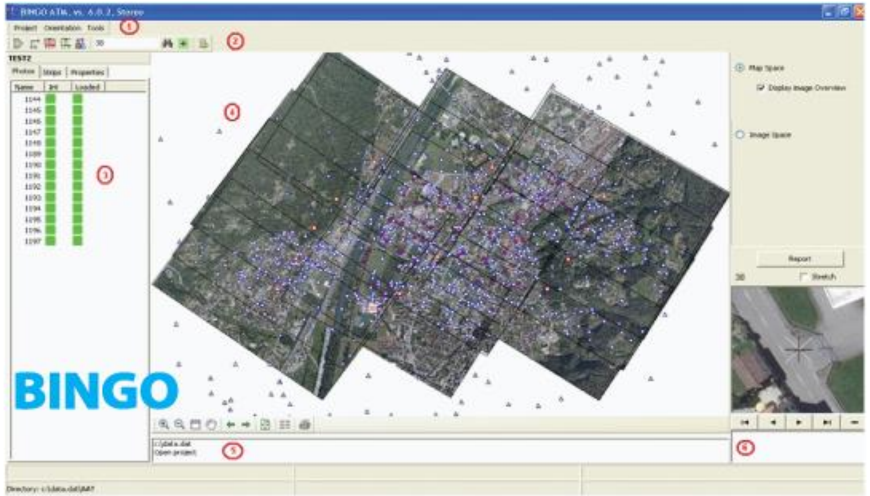
Current Softcopy Photogrammetric Systems





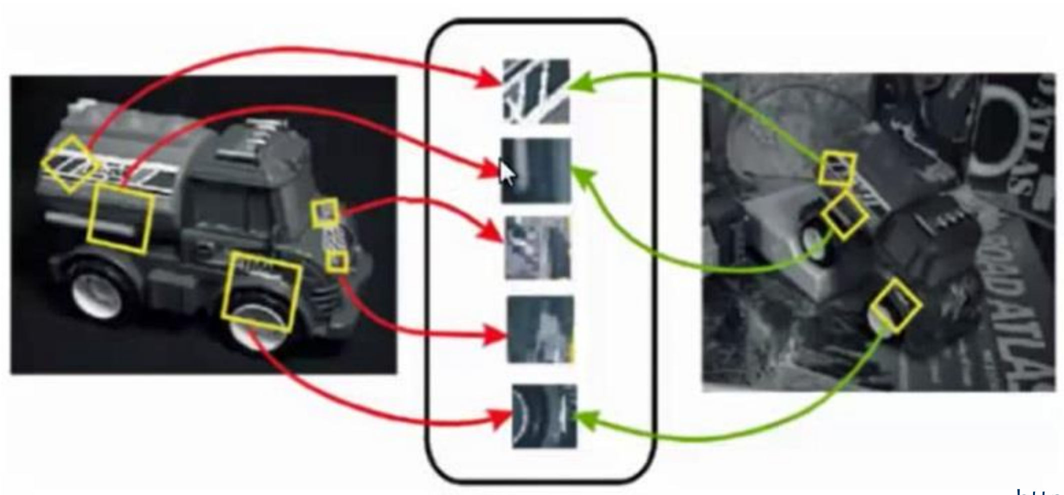
Modern Typical Methods – fast and accurate image matching

- **RANSAC** method find epipolar geometry
- Efficient and fast detection algorithm
- User defines number of points per image and matching method
- Both Matching method are used default by BINGO Dr. Kruck & Co. GbR

Random Sample Consensus (RANSAC); Fischler and Bolles, 1987)

SIFT

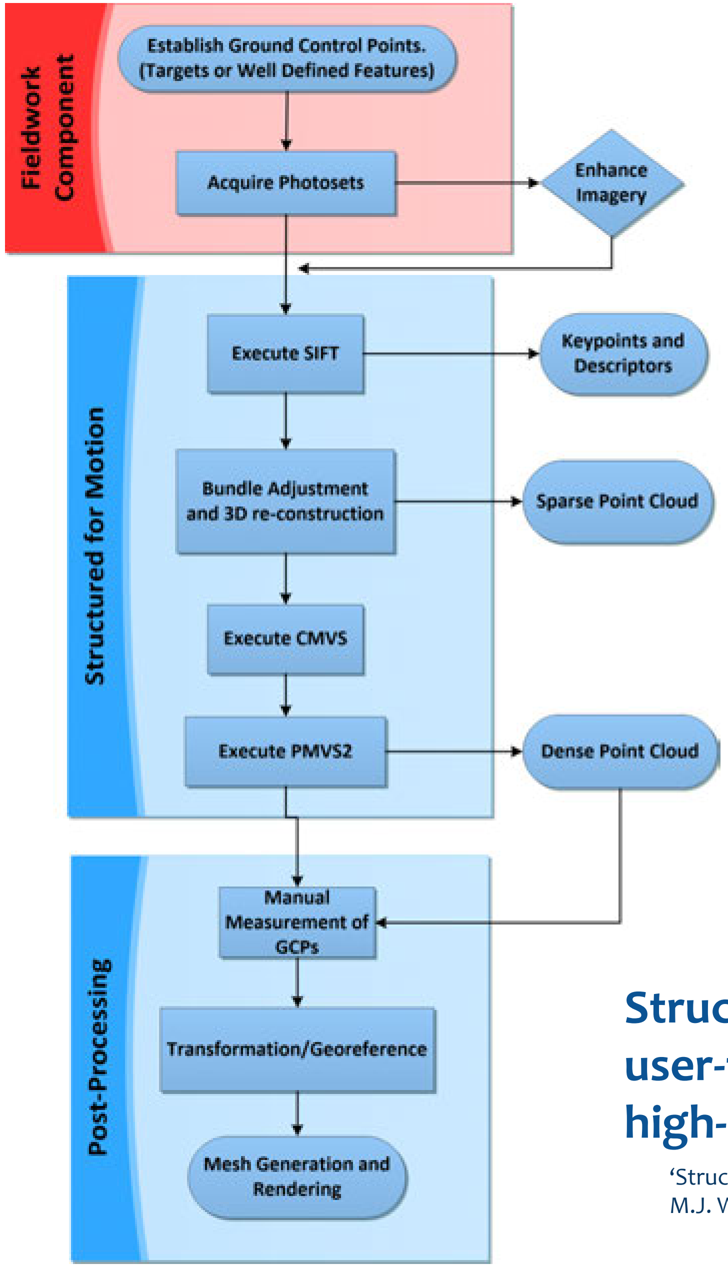
Scale-Invariant Feature Transform (or SIFT) is an algorithm in computer vision to detect and describe local features in images. The algorithm was published by David Lowe in 1999.



https://www.youtube.com/watch?v=NPcMS49V5hg

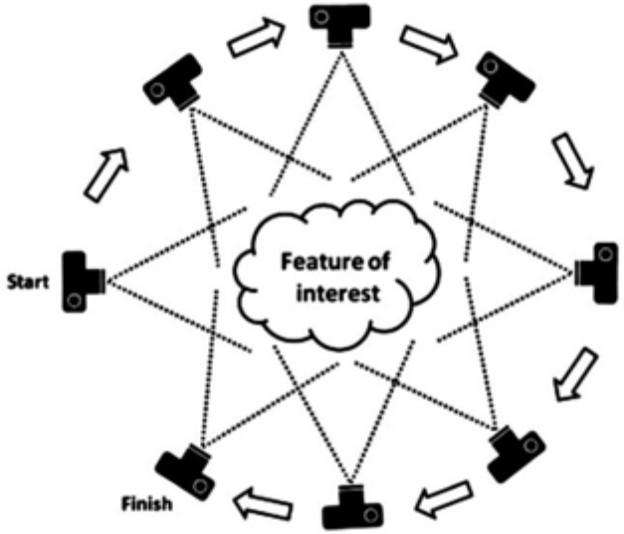
Applications include object recognition, robotic mapping and navigation, image stitching, 3D modeling, gesture recognition, video tracking, individual identification of wildlife and match moving

From Photo to Point Cloud
Structured from Motion (SfM) Workflow



- Pix 4D Mapper
- Agisoft
- 3D Correlator
- Bentley "Context Capture"
- Umapv
- Geoverse

- Leica tridicon
- Trimble
- Topcon



Structure from Motion (SfM) revolutionary, low-cost, user-friendly photogrammetric technique for obtaining high-resolution datasets at a range of scales.

'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications
M.J. Westoby a,⁎, J. Brasington b, N.F. Glasser a, M.J. Hambrey a, J.M. Reynolds

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Agisoft (SfM) App using
Digital Metric Sensor Images

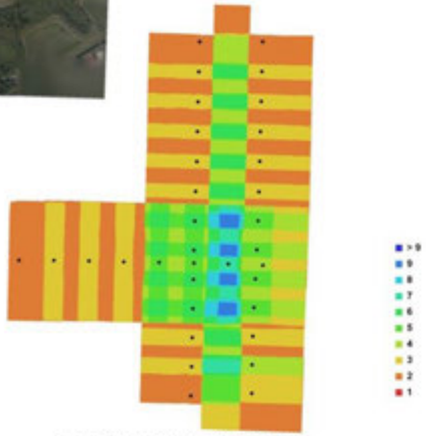

Fig. 1. Camera locations and image overlap.

Number of images:	35	Camera stations:	35
Flying altitude:	725.928 m	Tie-points:	6932
Ground resolution:	0.07773 m/pix	Projections:	23380
Coverage area:	3.63716 sq km	Error:	0.963875 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
RCD30 (53 mm)	9000 x 6732	53 mm	unknown	No

Table. 1. Cameras.

Ground Control Points

Fig. 3. GCP locations.

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
101	-0.005215	0.007036	0.023993	0.025541	2	0.007865
102	0.005356	-0.005063	-0.003560	0.008185	4	0.023982
103	-0.001177	0.000888	-0.000185	0.001486	3	0.028794
104	0.002565	0.005624	-0.005179	0.008064	3	0.021891
105	0.006272	-0.007236	-0.009041	0.013169	2	0.009664
106	-0.017874	-0.004956	-0.005538	0.019357	4	0.057907
107	0.033101	0.000484	0.002621	0.033208	7	0.088519
108	-0.011591	0.011457	0.002533	0.016493	3	0.071241
109	-0.001159	-0.005028	0.008230	0.009714	2	0.002236
110	-0.000629	0.001294	-0.004126	0.004369	2	0.001658

Camera Calibration

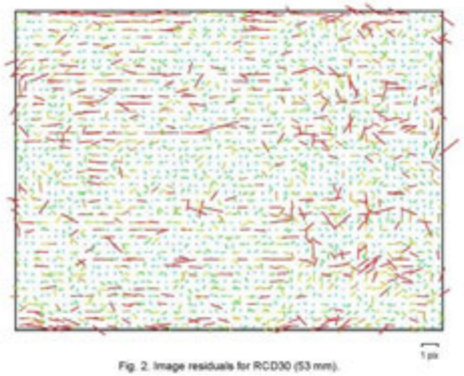

Fig. 2. Image residuals for RCD30 (53 mm).

RCD30 (53 mm)

Type:	Frame	K1:	0.000734446
Fx:	8799.3	K2:	-0.00602241
Fy:	8797.38	K3:	0.0120646
Cx:	4551.93	K4:	0
Cy:	3373.86	P1:	0.000309445
Skew:	-0.370256	P2:	0.000681187

Digital Elevation Model

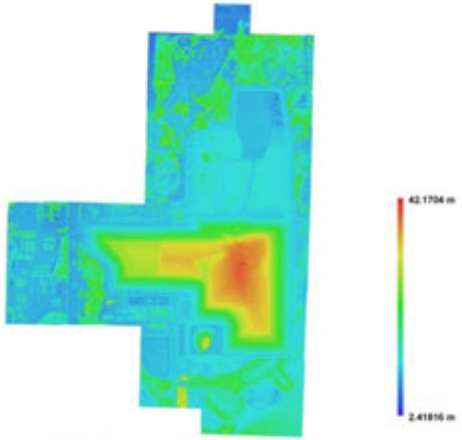

Fig. 4. Reconstructed digital elevation model.

Resolution:	0.15546 m/pix
Point density:	41.3774 points per sq m

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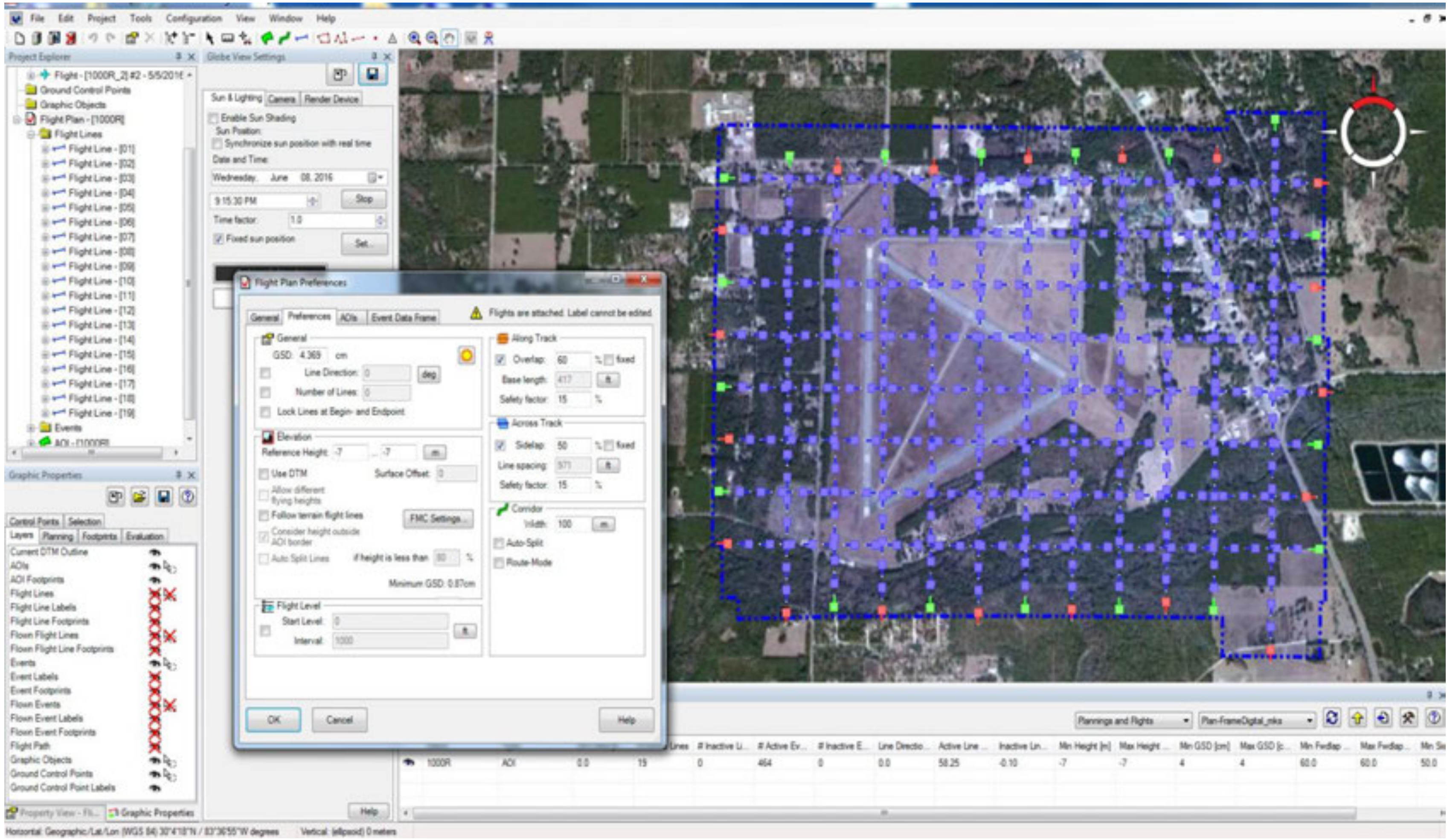
FDOT Flight Planning – Leica Mission Pro



IMU/GPS boresight and Multi-ray Photogrammetry testing

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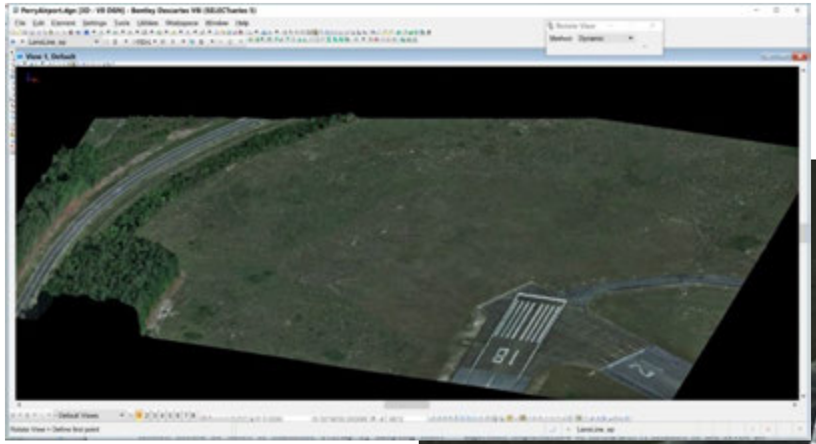
Perry Airport FDOT boresight

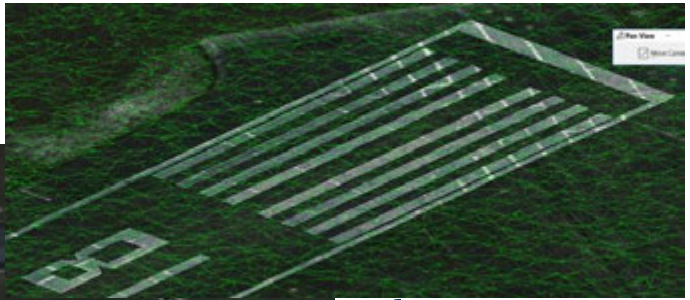
Perry Airport 2.5 D surface - Over 300 images Bundle Adjusted with Bentley's ***Context Capture***

Imagery from FDOT-SMO -   Zeiss DMC (2003) digital camera equipped with an upgraded CCD sensor

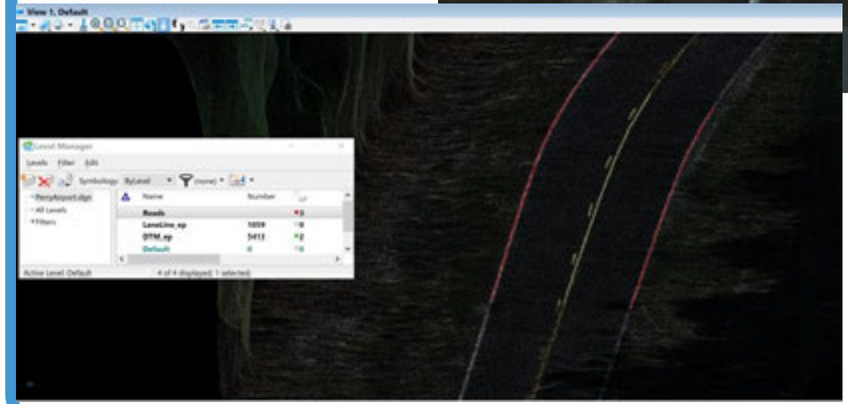
2.5D surface Generated using Bentley's Context Capture

Perry Airport FDOT boresight
Point Cloud in Microstation Descartes

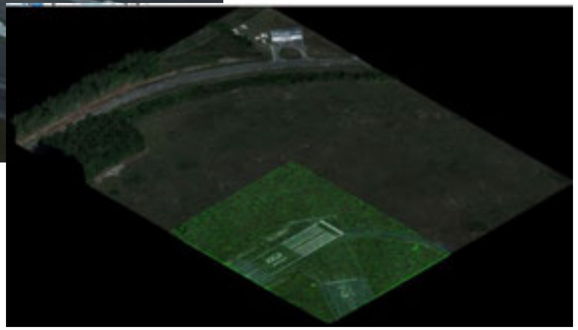




Close-up TIN



Digitized line features



Generate DTM

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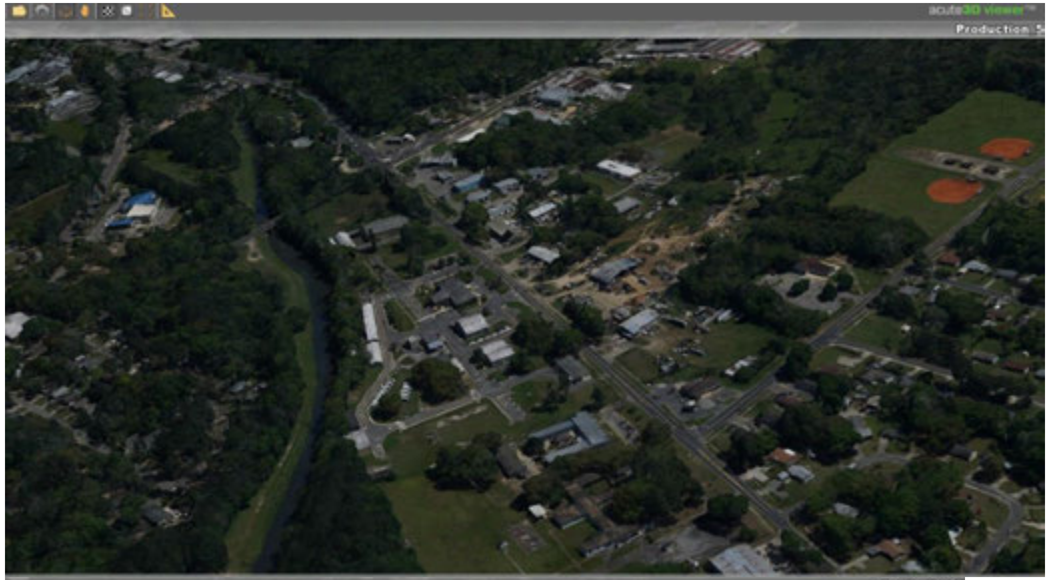
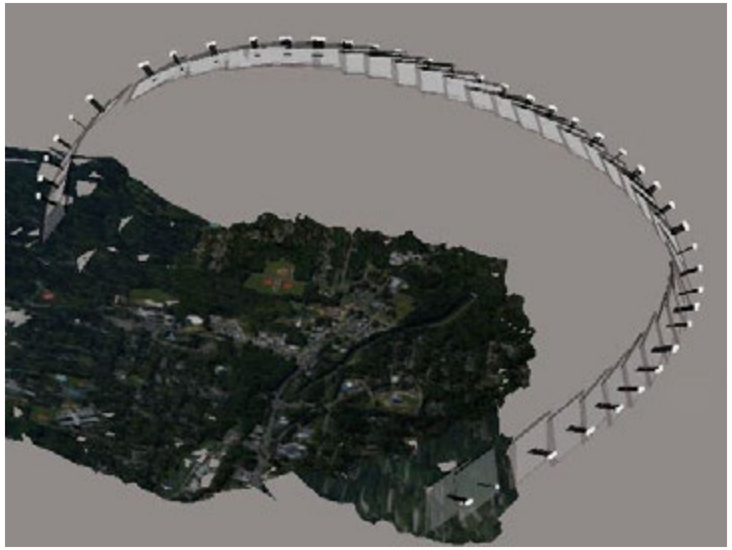
TERL Site- Tallahassee

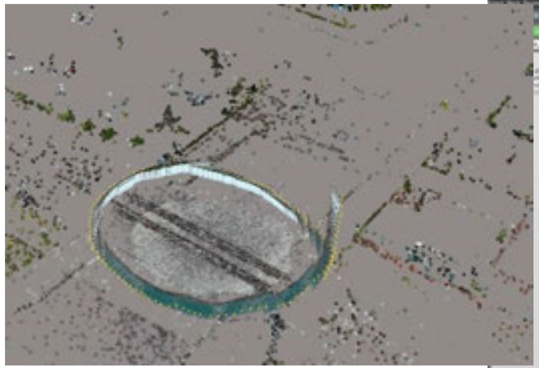


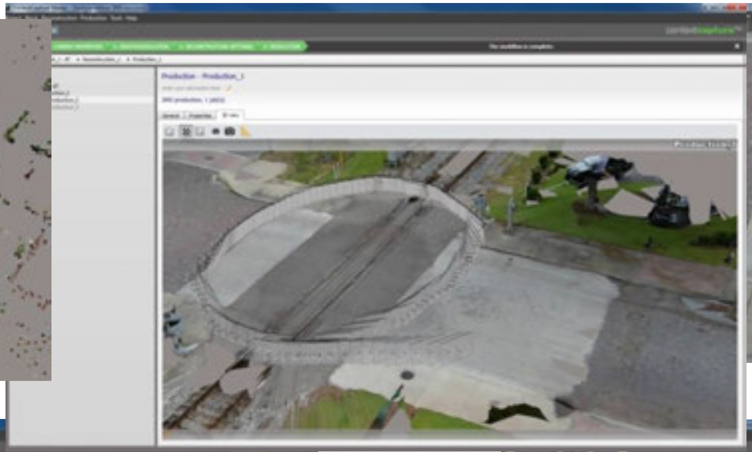


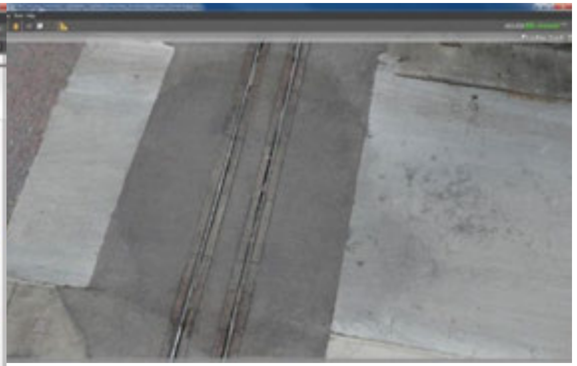
Sony A6000

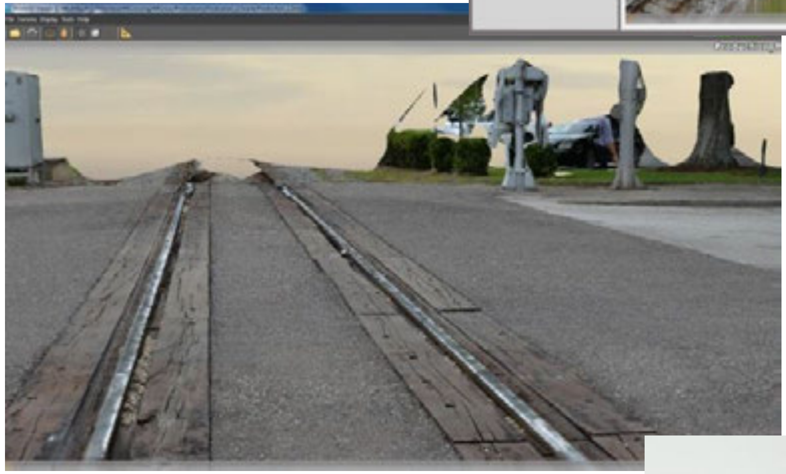
Focal Length (f)	50
Pixel Size (Ps)	3.9
Swath Along	4000
Swath Across	6026

Inspections w/ Nikon Df









Focal Length (f) mm	50
Pixel Size (Ps) microns	5.2
Swath Along -pixels	4596
Swath Across -pixels	6923

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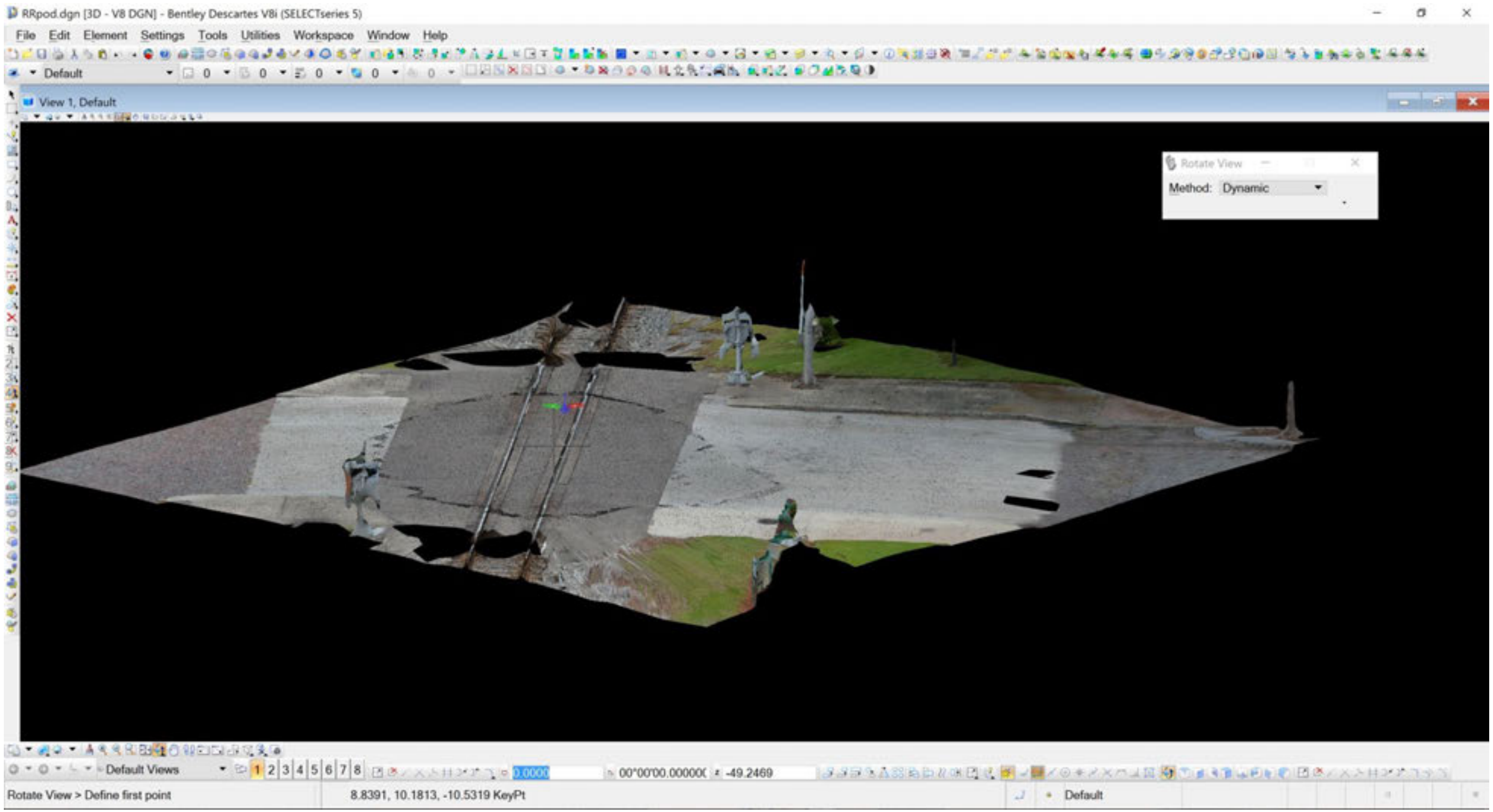
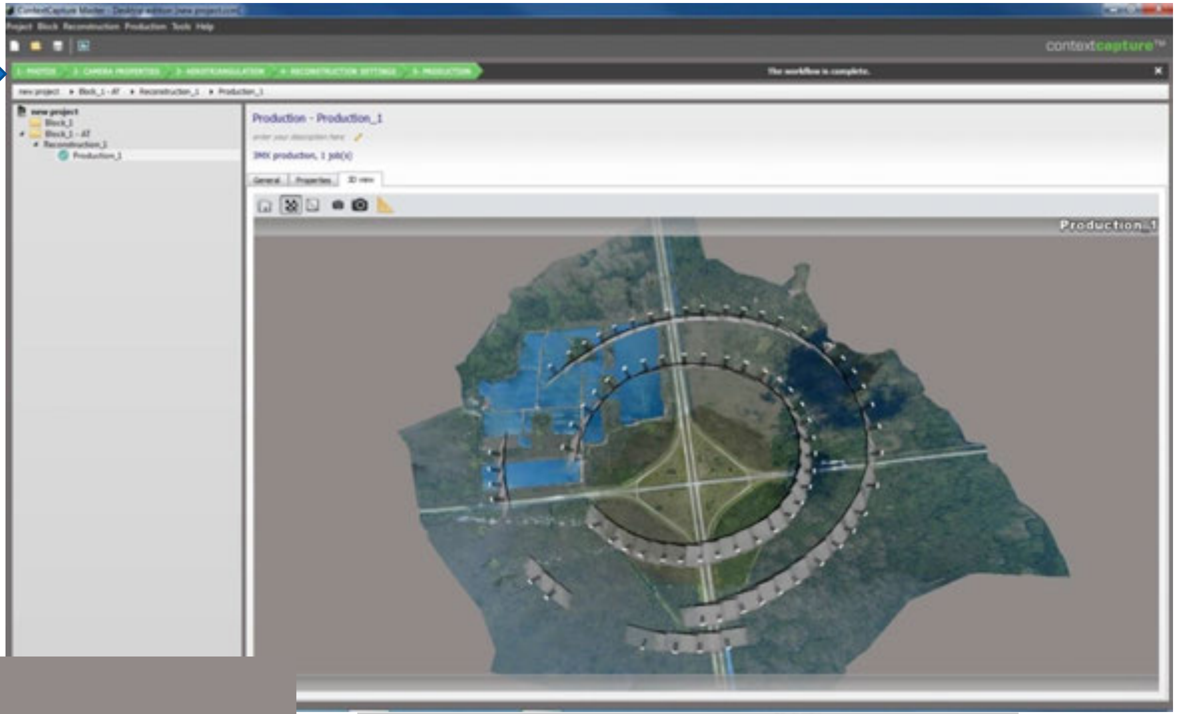
Exported as POD file to Bentley Descartes

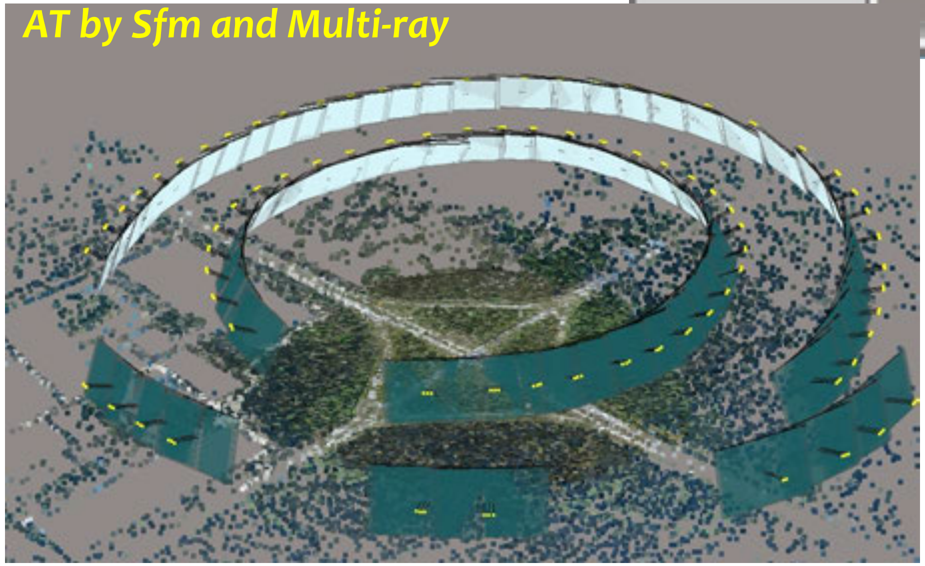


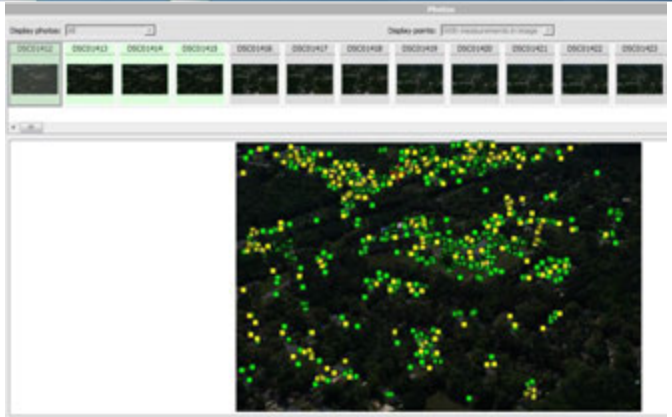
HWY Intersection w/ Nikon Df

Context Capture Workflow



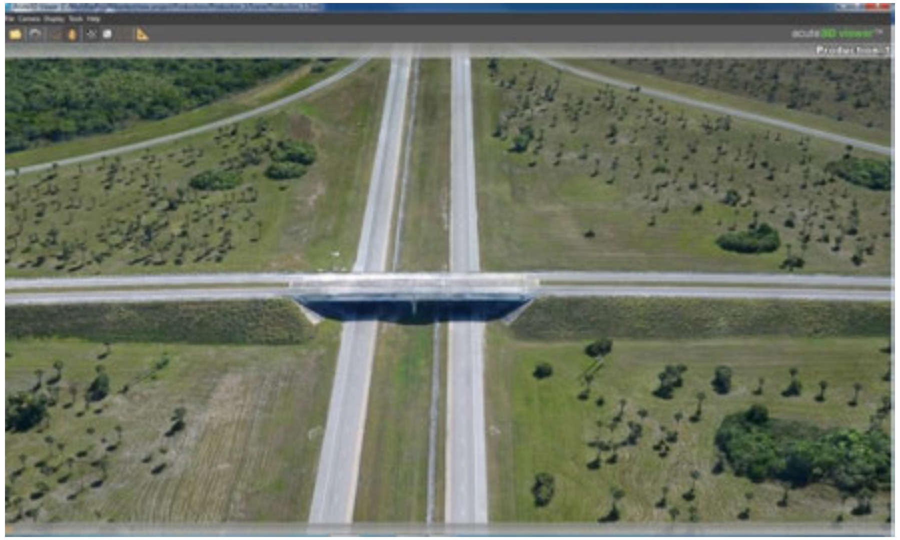
Nikon Df

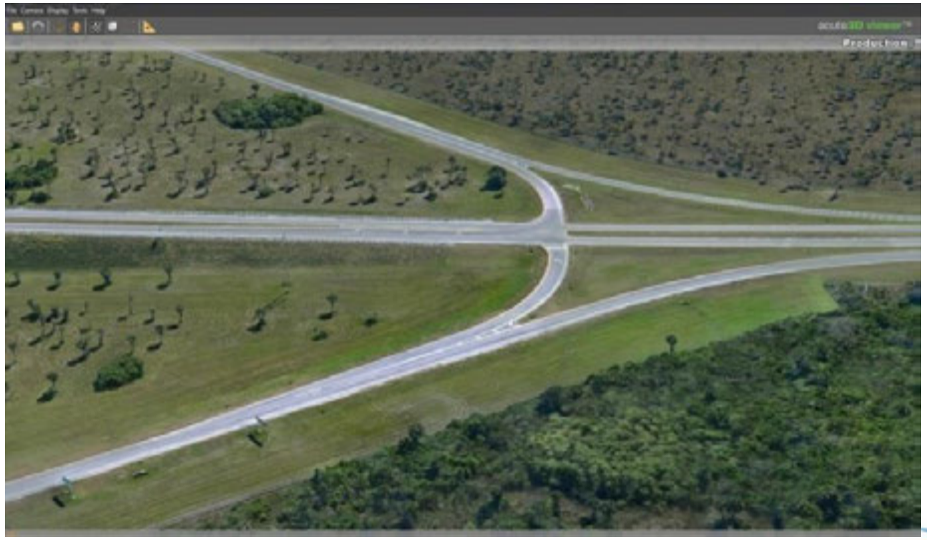




Tie or Key Points

Final Textured 3D Surface





Photogrammetric Capture - The ‘3 x 3’ Rules

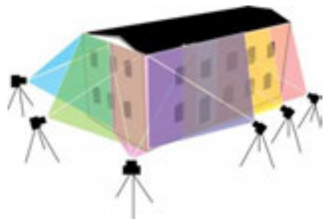
3 .1 THE GEOMETRIC RULES

1.1 – CONTROL

- Measure long distances between well-define points
- Define a minimum of one vertical distance (either using plumb line or vertical features on the object) and one horizontal.
- Do this on all sides of the object for control
- Ideally, establish a network of 3D coordinated targets or points from a loop traverse around the object.

1.2 - STEREO PHOTOCOVER

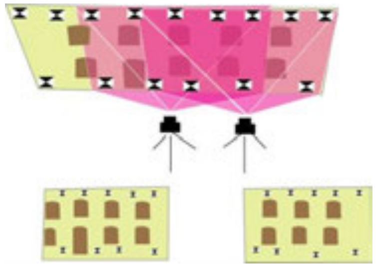
- Take a ‘ring’ of pictures around the subject with overlap of at least 60%. Some software needs 80% overlap.
- Take shots from a height about half way up the subject if possible.
- Include the context or setting ground line, skyline, etc.
- At each corner of the subject take a photo covering the two adjacent sides.
- Include the top, if possible (Aerial Obliques).
- No image should lack overlap.
- Add orthogonal, full facade shots for an overview and rectification.



1.3- DETAIL STEREO PHOTOCOVER

Stereo-pairs should be taken:

- Normal case (base-distance-ration 1:4 to 1:15), and/or
- Convergent case (base-distance-ratio 1:1 to 1:15).
- Close-up ‘square on’ stereo-pairs for detail
- Measure control distances within overlaps
- Check photography overlaps. If in doubt, add more shots
- Measured distances for any potentially obscured areas.
- Make sure enough control (at least 4 points is visible in the stereo image area.



3 .2 - THE CAMERA RULES

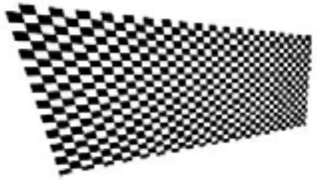
2.1 - CAMERA PROPERTIES

- Fixed optics if possible. No zooming! Fully zoom-out. Do not use shift optics. Disable auto-focus.
- Fixed focus distance. Fix at infinity or a mean distance using adhesive tape, but only use one distance for close-ups.
- The image format frame of the camera must be sharply visible on the images and have good contrast.
- The true documents are the original dia-positives, negatives, or digital ‘RAW’ equivalents. Set camera to use the camera its highest quality format.

2.2 - CAMERA CALIBRATION

Use the best quality, highest resolution and largest format camera available.

- ‘Medium’ format is better than a small format.
- A larger sensor is better than a smaller one.
- A wide-angle lens is better than a narrow angle for all round
- photograph. Very wide-angle lenses should be avoided.
- Calibrate the camera with a fixed focus lens and tape it there.
- Standard calibration information is needed for each camera/lens
- combination screen before capture with each lens will help.
- A standardized color chart should be used in each sequence of frames.



2.3- IMAGE EXPOSURE

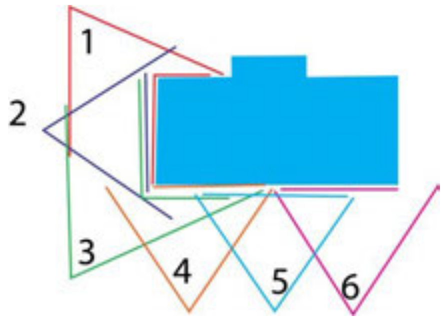
Consistent exposure and coverage is required.

- Work with consistent illumination: beware deep dark shadows.
- Use a lighting rig.
- Use HDR to capture difficult, unbalanced exposures.
- Plan for the best time of the day.
- Use a tripod and cable release/remote control to
- avoid camera movement and get sharp images.
- Use a panoramic tripod head to get parallax-free panoramic
- imagery.
- Use the right mode: BW is best for tracing detail
- but color is good for recording material type and pigment.
- Use RAW or ‘high quality’ and ‘high sensitivity’ setting on
- digital cameras.
- Geotag the images. (**pose or EO**)

3. 3 - THE PROCEDURAL RULES

3.1 - RECORD PHOTO LAYOUT

- The ground plan with the direction of north indicated
- The elevations of each facade (at an appropriate scale 1:50, 1:100 - 1:500).
- Photo locations and directions (with frame numbers).
- Single photo coverage and stereo coverage.
- Control point locations, distances and plumb-lines.
- If using ‘natural (photo)’ points a clear diagram showing each point is required.



3.2 - LOG THE METADATA Make witnessing diagrams of:

- Site name, location and geo-reference,
- Owner’s name and address.
- Date, weather and personnel.
- Client commissioning body, artists, architects, permissions, obligations, etc.
- Cameras and optics, focus and distance settings.
- Calibration report, including the geometric and radiometric results if available.
- Description of place, site, history, bibliography, etc.
- Remember to document the process as you go.

3.3 - ARCHIVE Include the following:

- Data must be complete, stable, safe and accessible:
- Check completeness and correctness before leaving the site.
- Save images to a reliable location off the camera.
- Save RAW formats and TIFF copies.
- Remember a DVD is not forever !
- Write down everything immediately
- The original negatives/dia-positives/RAW files are archive documents.
- Treat and keep them carefully.
- Don’t cut into the format if cutting the original film. If using digital cameras,
- don’t crop any of the images and use the full format.
- Ensure the original and copies of the control data, site diagrams and
- images are kept together, as a set, at separate sites on different media.

http://cipa.icomos.org/fileadmin/template/pdf/3x3-23_10_2013.pdf

Earthworks Survey

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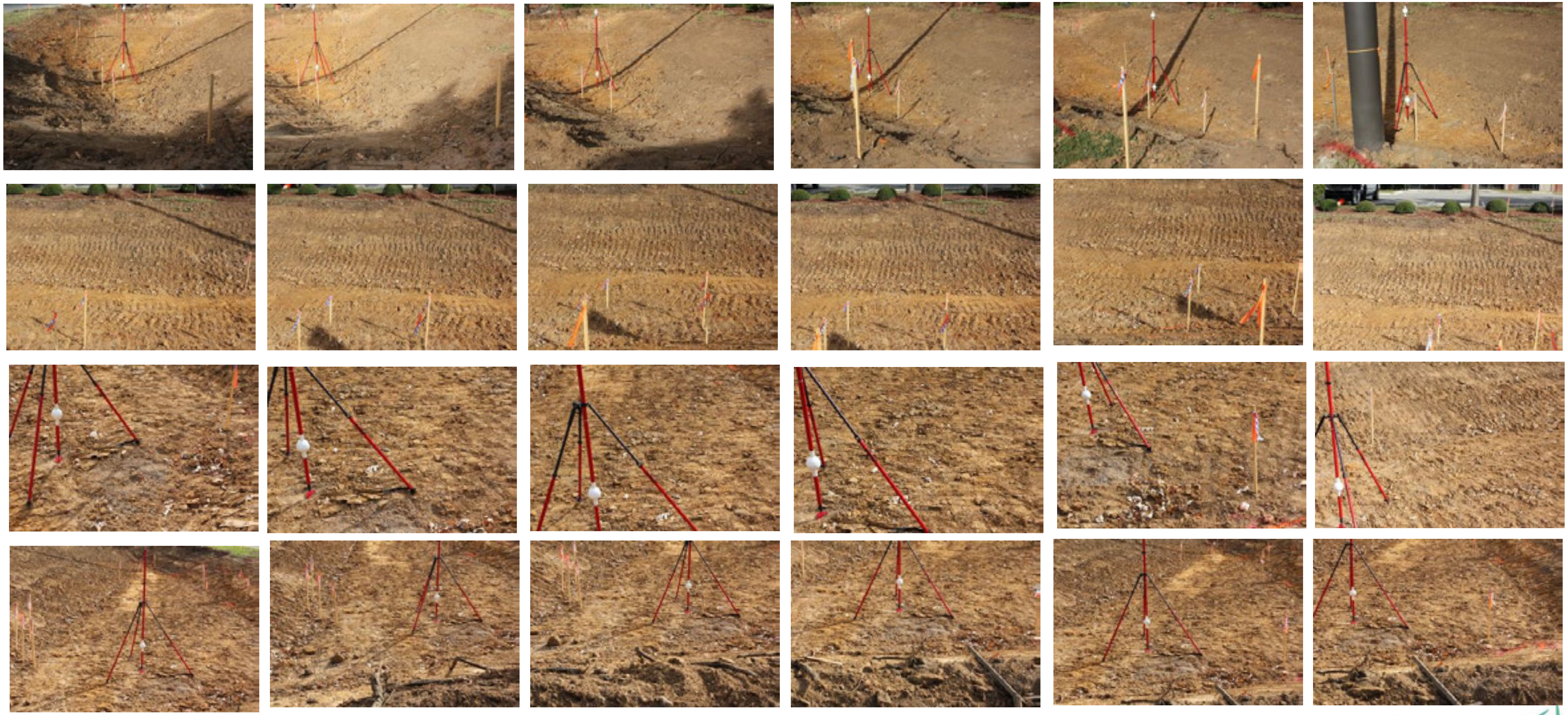
Ground Control Points

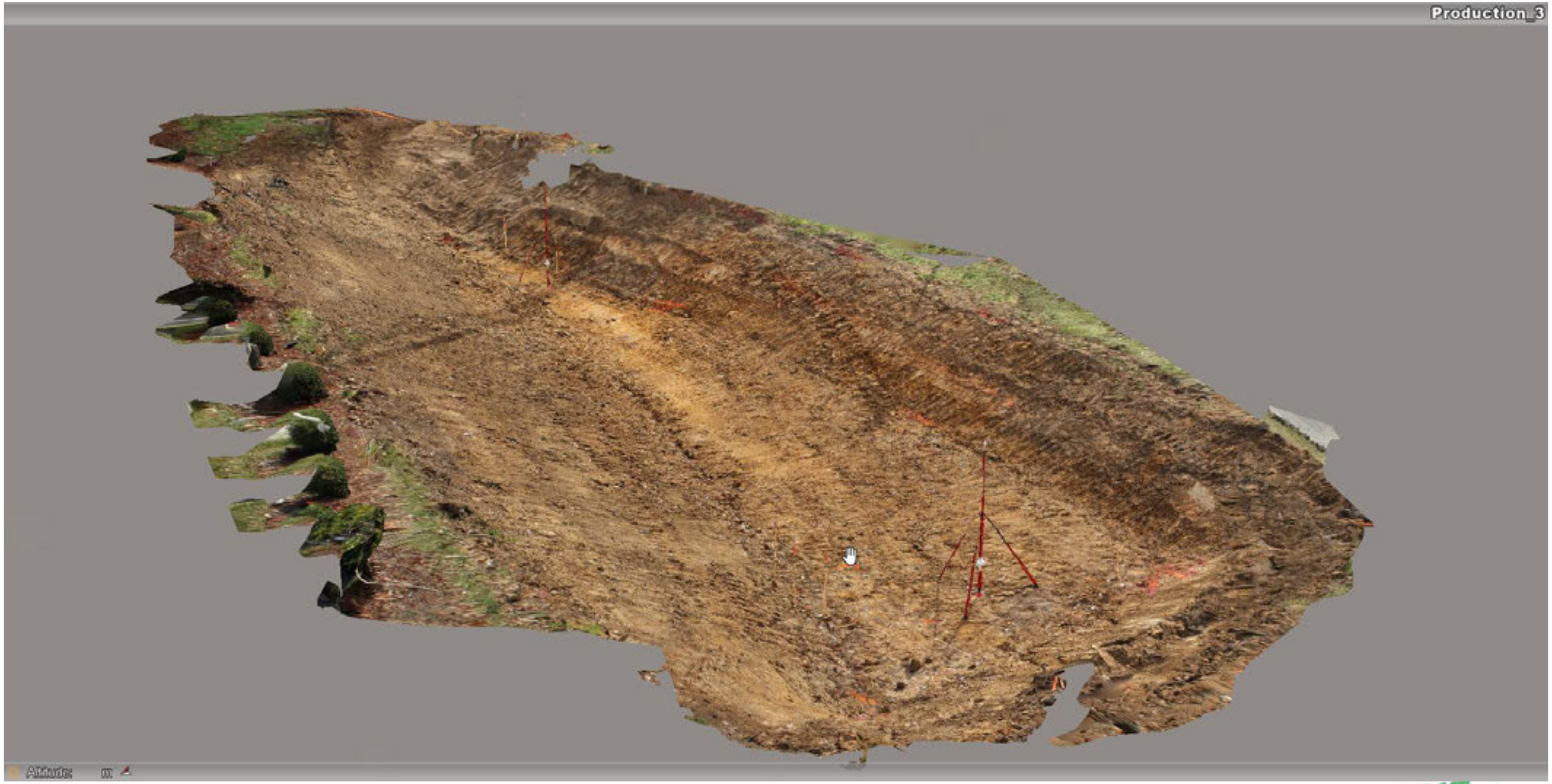
For Affine Transforms
3 or More GCPs laid out in grid pattern is optimum.

PID,N,E,Z   LL WGS84
6,30.436890915195502,-84.274244734871402,30.942
5,30.436893077778482,-84.274259106846131,30.956
4,30.436916750462579,-84.274281393718539,30.949
3,30.436910789491982,-84.274240358683386,30.964
2,30.437032422138138,-84.274233011989523,31.553
1,30.437036319796153,-84.274207122513403,30.994

Image Capture



Multi-ray MODEL



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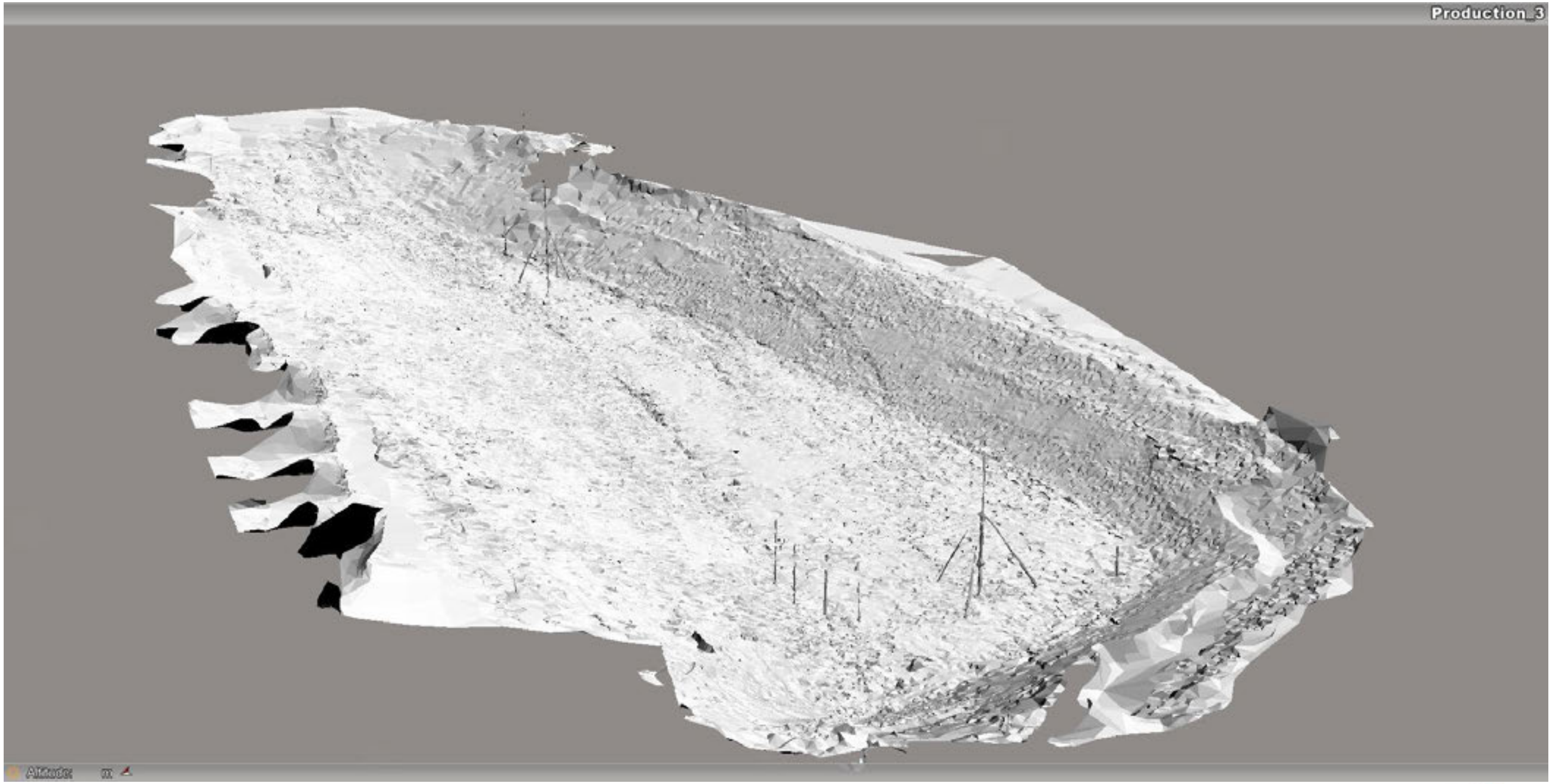
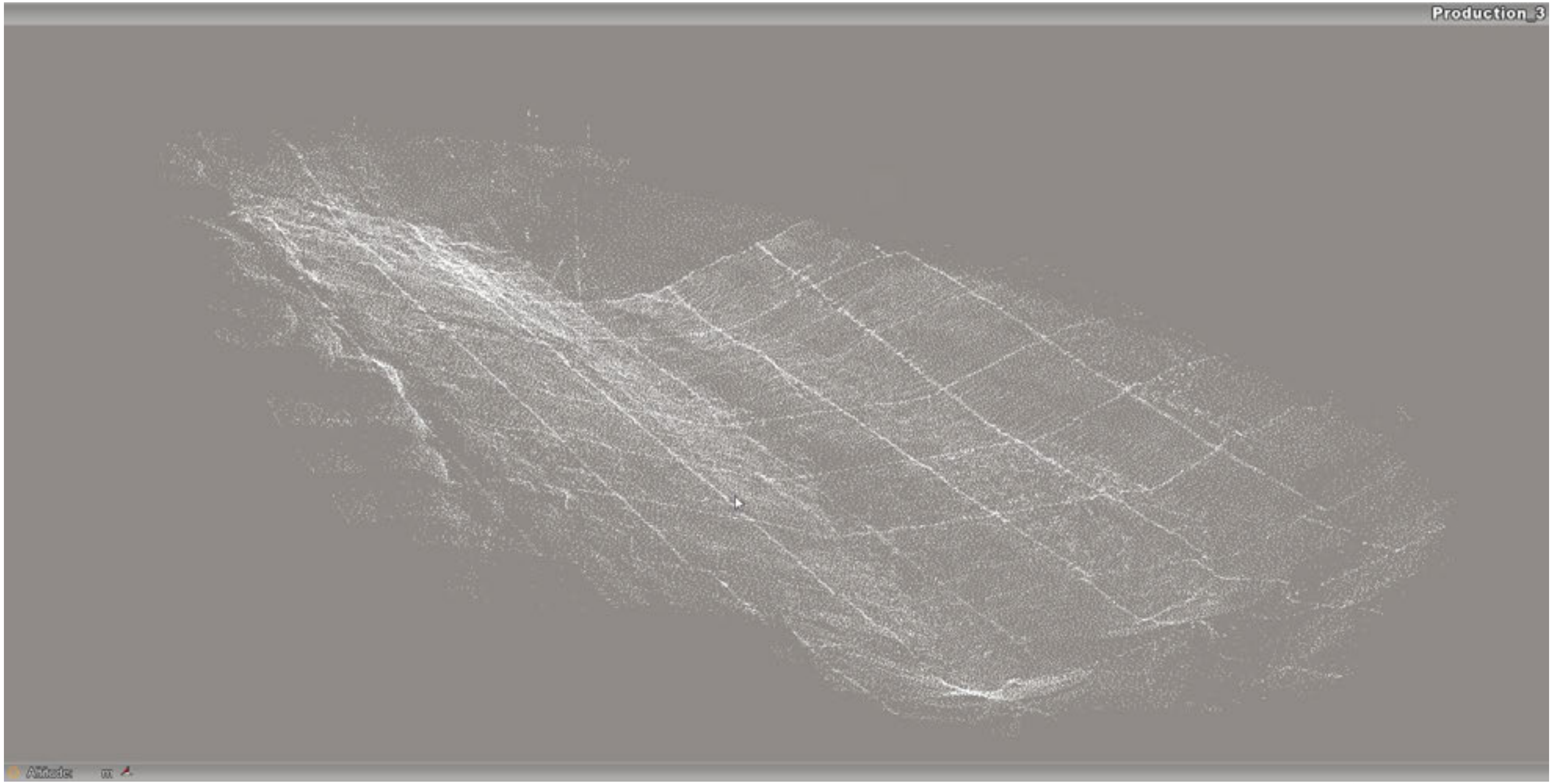
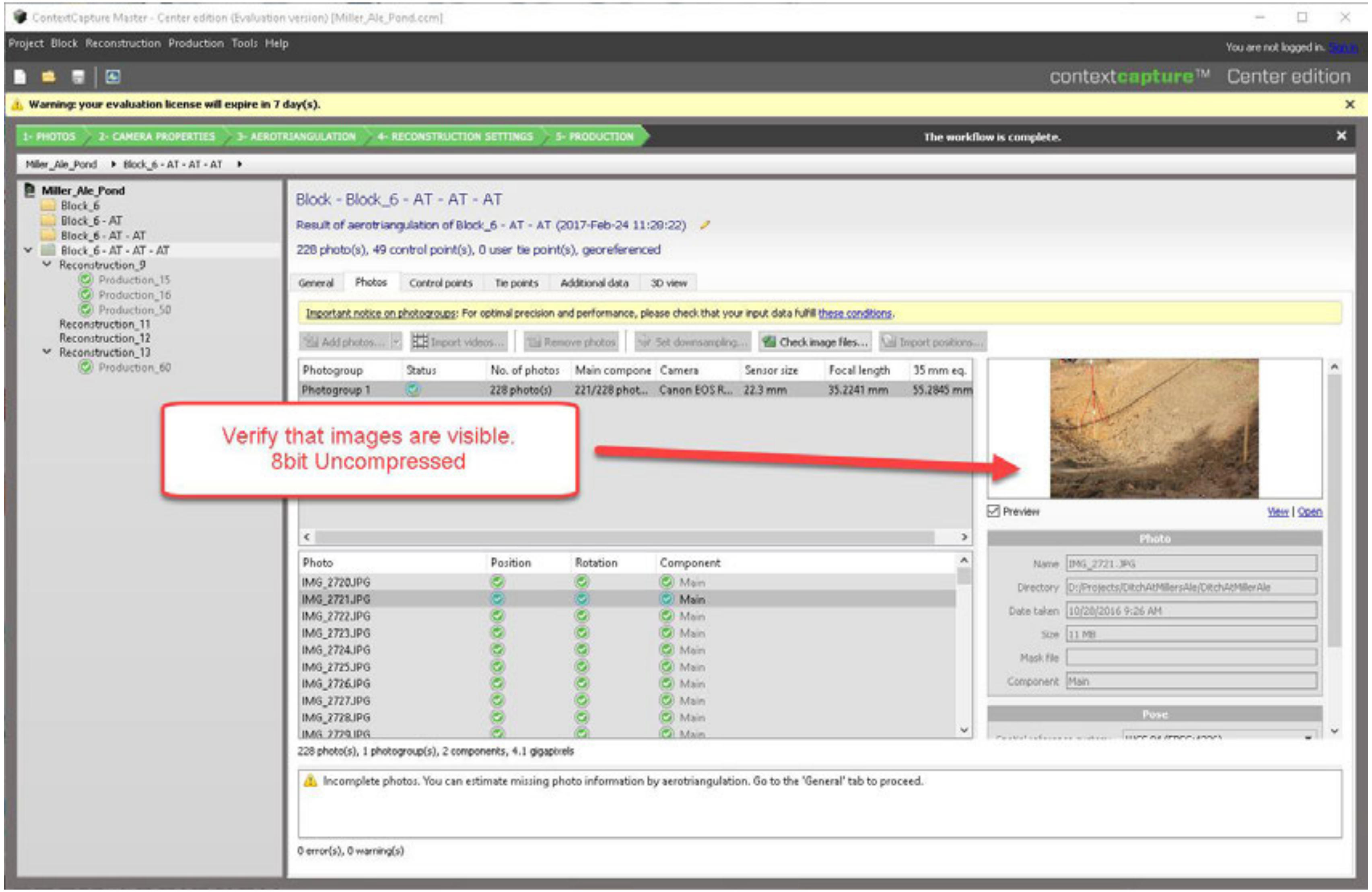
WIREFRAME MODEL



DSM Point Cloud



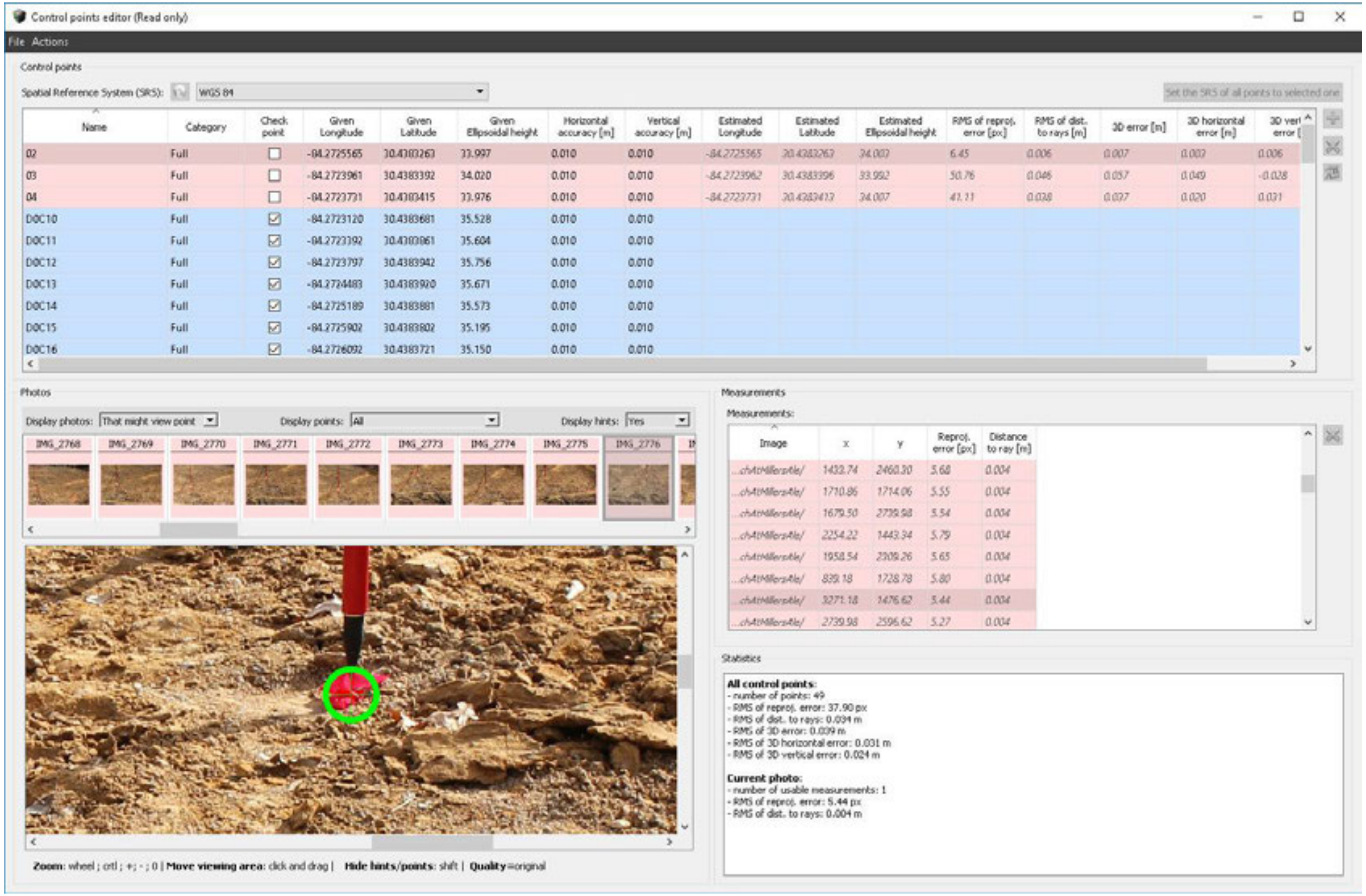
Context Capture TIPS for TIFF 8bit uncompressed



- •JPEG
- •Tag Image File Format (TIFF)
- •Panasonic RAW (RW2)
- •Canon RAW (CRW, CR2)
- •Nikon RAW (NEF)
- •Sony RAW (ARW)
- •Hasselblad (3FR)
- •Adobe Digital Negative (DNG)

- •Audio Video Interleave (AVI)
- •MPEG-1/MPEG-2 (MPG)
- •MPEG-4 (MP4)
- •Windows Media Video (WMV)
- •Quicktime (MOV)

Good Quality and Location of Ground Control Points (GCP)



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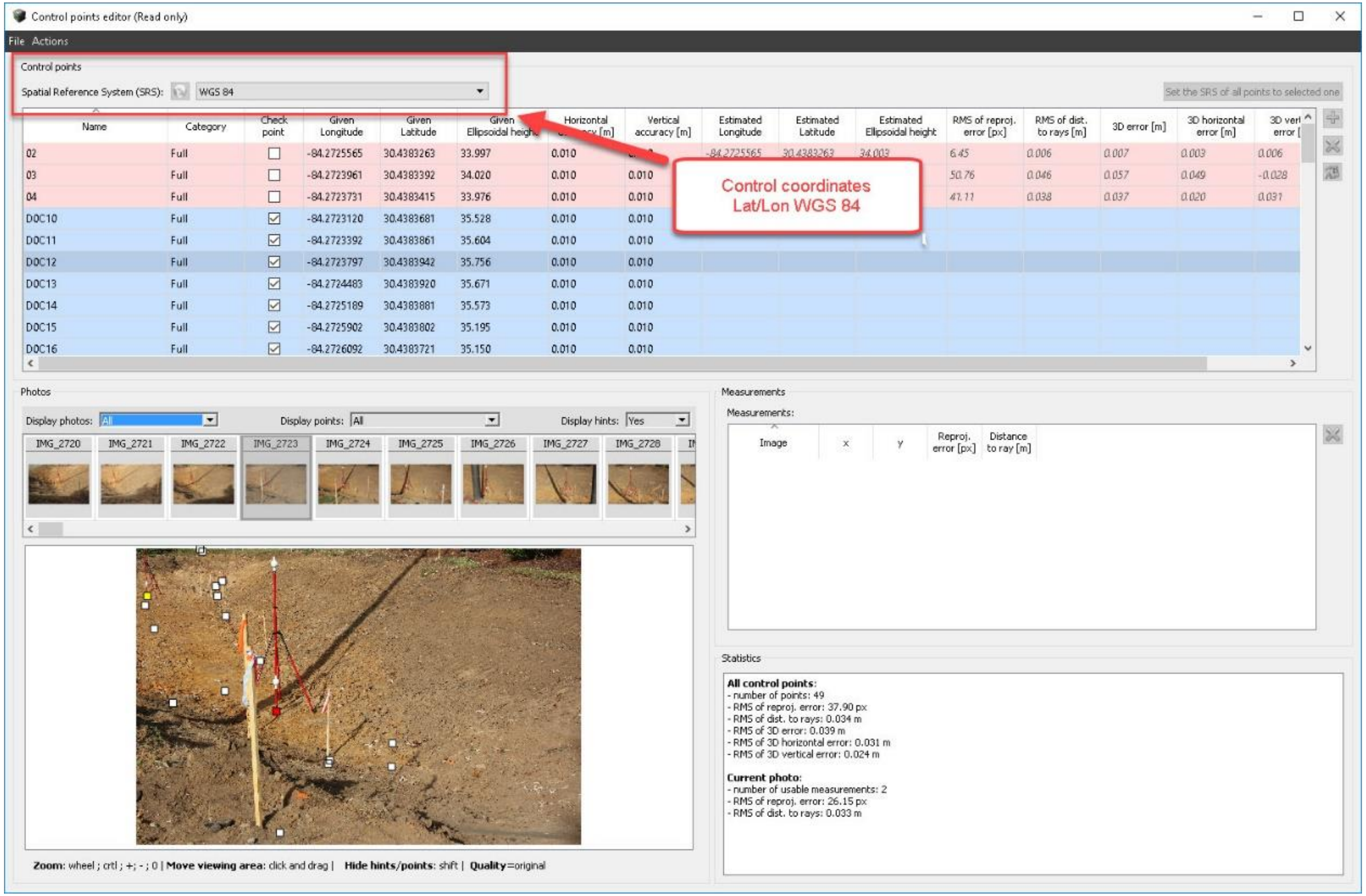
Coordinate System LL WGS 84

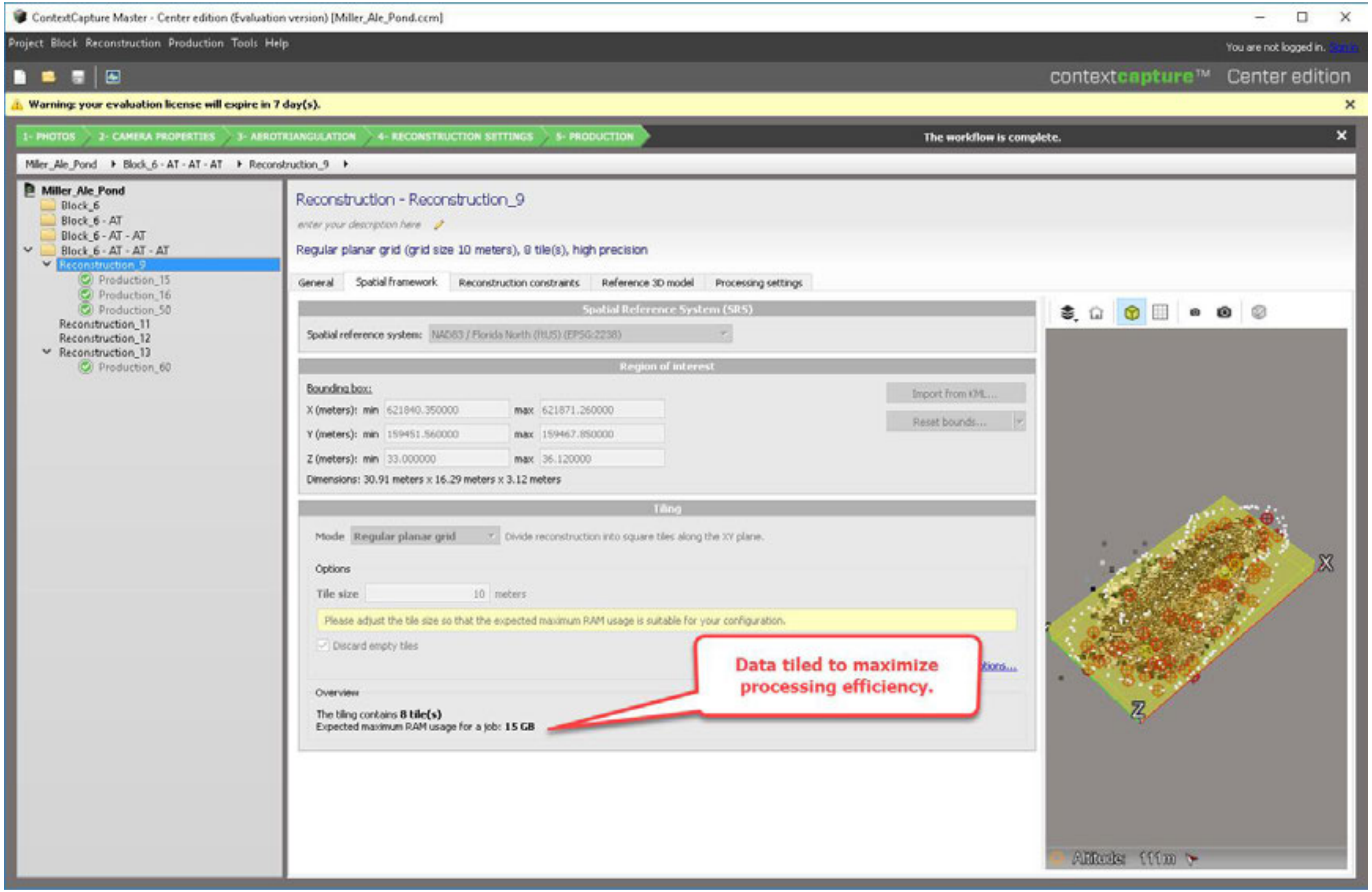


GPS tags, if present in Exif metadata or in an accompanying XMP file, are automatically extracted, and can be used to georeference the generated 3D model.

Incomplete GPS tags are ignored (with latitude and longitude coordinates but without altitude).

GPS altitude reference *Sea level* and *WGS 84 ellipsoid* are supported.

Set Data Tile Size to Maximize Processing Efficiency



Hardware Requirements for Context Capture

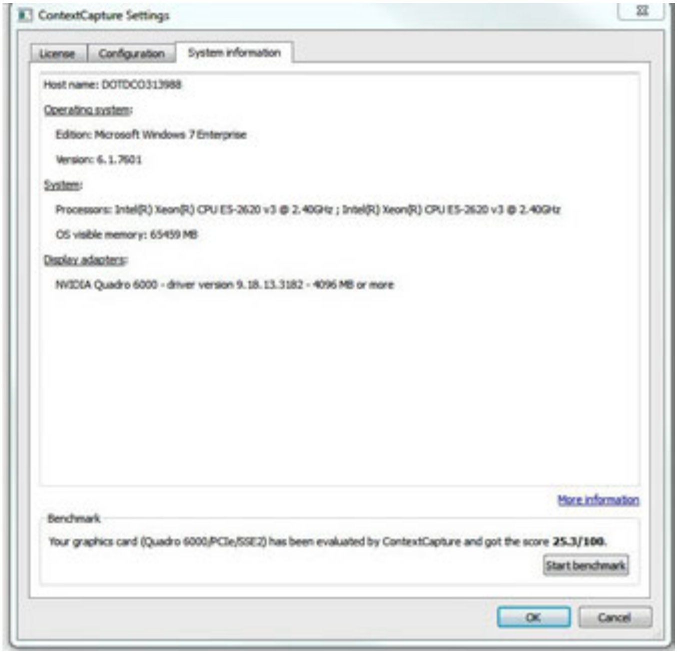
An **Adequate** graphics card that supports CUDA is very important !

- **CUDA Zone**

https://developer.nvidia.com/cuda-zone

CUDA® is a parallel computing platform and programming model invented by NVIDIA

- http://www.nvidia.com/object/imaging_comp_vision.html



	17.3" PLATFORM					15.6" PLATFORM		
GRAPHICS FEATURES	Quadro M5500	Quadro M5000M	Quadro M4000M	Quadro M3000M	Quadro M2000M	Quadro M1000M	Quadro M600M	Quadro M500M
CPU/Mobile Platform Generation	Skylake	Skylake	Skylake	Skylake	Skylake	Skylake	Skylake	Skylake
NVIDIA® CUDA® Parallel Processor Cores	2048	1,536	1,280	1,024	640	512	384	384
Memory Size	8GB	8GB	4GB	4GB	4GB	2GB/4GB	2GB	2GB

Processor: 2 - Intel Xeon®CPU ES-2620v3 @ 2.4GHz – 64G RAM
NVIDIA Quadro 6000 4G (GPU)

Performance

ContextCapture exploits the power of general purpose computation on graphics processing units (GPGPU), yielding 50-times faster processing for some operations (image interpolation, rasterization, z-buffering). It also uses multi-core computing to speed up some CPU-intensive parts of the algorithms.

ContextCapture can process 10 to 20 gigapixels per day and per ContextCapture Engine on average, depending on the hardware configuration, for the production of a textured 3D mesh with *Highest* precision.

You can dramatically reduce processing time with grid computing, simply by running multiple ContextCapture engines on several computers, and associate them to a same job queue.

Example: for vertical + 4-oblique aerial datasets with a ground resolution of 10-15 cm and a typical overlap, we have observed an average production rate of 30-50 km² per day on a cluster of 4 ContextCapture Engines.

Regarding memory use, one ContextCapture Engine with 8 GB of RAM can handle up to 1 gigapixel of input data and 10 million output triangles in one job.

Closing…..Questions?

FDOT

http://www.fdot.gov/geospatial/

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